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DEPARTMENT OF COMMERCE

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METHOD AND COST OF MINING SAND AND GRAVEL AT THE FARMINGTON (CONN.) PLANT OF THE ATLAS SAND, GRAVEL AND STONE CO.

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JOHN S. DUNNING

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METHOD AND COST OF MINING SAND AND GRAVEL AT THE FARMINGTON (CONN.) PLANT OF THE ATLAS SAND, GRAVEL AND STONE CO.[1]

By John S. Dunning[2]

INTRODUCTION

This paper is one of a series describing methods and costs of recovering sand and gravel from deposits in the United States and deals directly with the operations of the Atlas Sand, Gravel and Stone Co. at Farmington, Conn.

These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local expenditures only and not total production costs. It is recognized that publication of total costs might in some instances cause embarassment to individual producers, as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations may ensue.

The plant described is a dry-land operation of especial interest because its present methods of handling the material were developed by a series of radical changes each of which brought about greater economy and increased the quality and quantity of the product. The plant can now produce the finished material at a marked reduction from the cost of production in the plant as it was first built.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of S. N. Dunning, president of the company, in furnishing data, and of J. R. Thoenen, mining engineer of the U. S. Bureau of Mines, who helped in compiling this report.

HISTORY

The Atlas Sand, Gravel and Stone Co. began operations in 1913 at Farmington, Conn. The original plant consisted of three bins, above which were mounted a small jaw crusher and screening and washing apparatus. Material was drawn to the plant by a 1½-yard slack-line cable excavator.

It was not long before costs began to rise on account of the necessity of going further and further away for sand and gravel which was not too deep under water. It was found that the presence of occasional large bowlders on which the bucket would catch limited the use of the cable excavating system to dry material or at best to that in shallow water where the bowlders could either be blasted or removed by hand. The approximate limiting depth of water

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6676."

2 - One of the consulting engineers, U. S. Bureau of Mines; and engineer, Atlas Sand, Gravel and Stone Co.

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for economical operation of the slack-line cableway was found to be about 5 feet. However, if no large bowlders were encountered, dragging at each position was sometimes continued to a depth of 8 or 10 feet. The limiting depth, in other words, was determined by large bowlders rather than by the water itself. About 1916 the cable system was discarded in favor of a power shovel which loaded trucks. These trucks dumped into a hopper, and an inclined bucket elevator raised the material to the crusher.

About 1917 an effort was again made to reclaim the under-water deposit near the plant by the use of a crane mounted for railroad traction with clamshell attachment.

A line of track was run parallel to one side of the deposit to be worked and the clamshell excavated on that side of the track. Since the deposit is so tightly packed, excavation could be carried quite close to the track. Then the track would be moved back from the excavation and the clamshell would take another strip. This method of operation was not developed because the deposit was found to be too tightly packed to be dug efficiently by the clamshell bucket. Consequently it was soon replaced by the present set-up, consisting of a power shovel and industrial railway system.

During this time the screening tower was rebuilt three times, and enlarged each time, until now it has bin storage space for 8 different sizes of material totaling about 400 tons. All crushers were removed from the tower and placed on the ground, and a belt conveyor is used to elevate the crushed material.

Considerable difficulty was experienced in getting enough water for washing the increasing output of the plant. After several unsuccessful attempts to drill wells to provide sufficient water, an 8-inch pipe line was run about 1,000 feet to the Farmington River, which gave ample washing water for a clean product. This water had to be raised a vertical distance of 22 feet, of which 8 feet was suction head and 14 feet discharge head.

GEOLOGY

Geologically the deposit falls within the area defined by Flint[3] as of glaciolacustrine origin. The materials were deposited on the beds of ancient glacial lakes formed by the impounding of glacial waters behind ice gorges. The many lacustrine terraces occurring in this section are differentiated by their elevation above sea level.

There is a certain amount of horizontal stratification present, although the distribution of sand and gravel is rather uniform throughout the deposit. There are minor variations, however, as exemplified by the occurrence of thin layers of sand with no gravel.

Scattered throughout the deposit and in some instances collected in local clusters are bowlders of soft sandstone. These have evidently been brought to the lake by ice or glaciofluvial waters and left in place as the boundaries of the lakes contracted.

The deposit extends several miles north and south of Farmington, roughly paralleling the Connecticut River lying 10 miles to the east. The tracks of the New York, New Haven, and Hartford Railroad form the west boundary of the property and there is a siding about ½ mile north of the plant. It is one of many deposits of sand with more or less gravel in the northwestern section of the State. The deposits are usually easily recognized by the sparse clumps of sedge and gray birches which with a few cottonwoods and scrub oaks almost invariably form the only vegetation. Figure 1 is a sketch of the land owned by the company and shows the general location of the plant and pit.

The overburden on this deposit is a light sandy loam varying from 1 to 3 feet in depth. Gravel and sand are stratified horizontally, but the bank runs quite uniformly about 40 per cent sand. Occasional bowlders of soft red sandstone occur which would crush into poor ag-

3 - Flint, R. F., The Glacial History of Connecticut: Bull. 47, Conn. Geol. and Nat. Hist. Surv., 1930, pp. 294.

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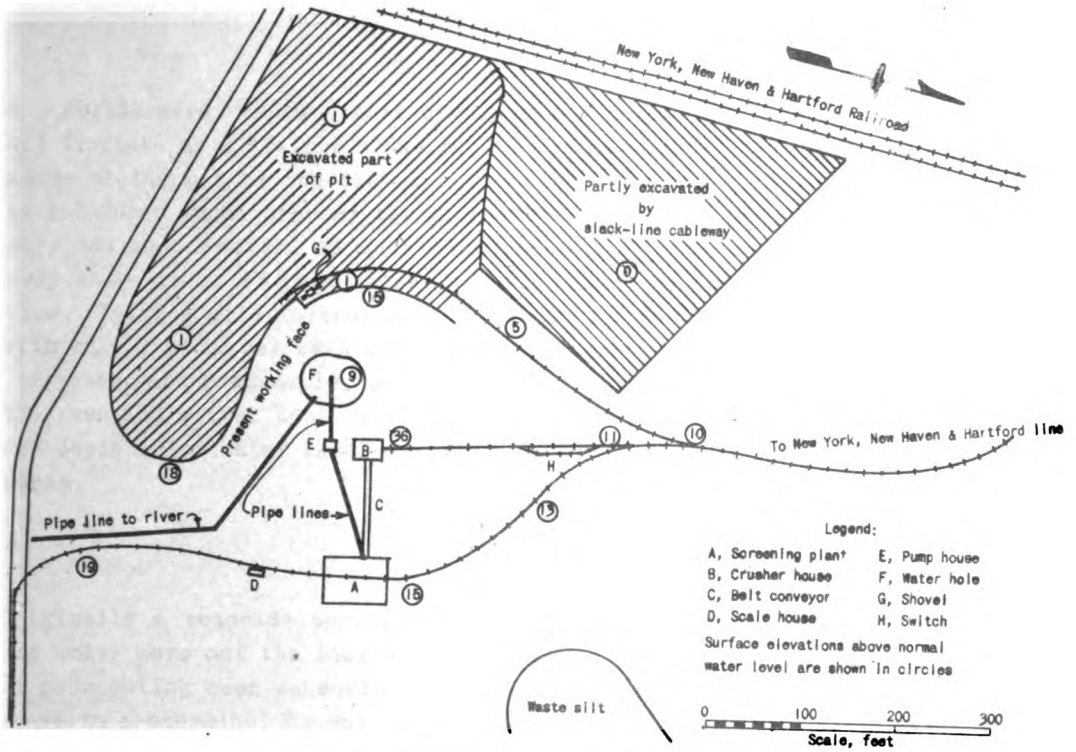
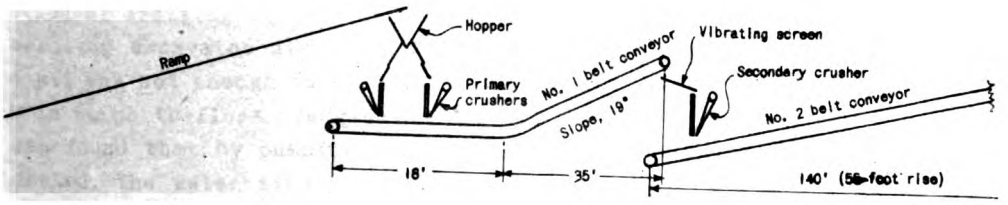


Figure 1.- Map of property



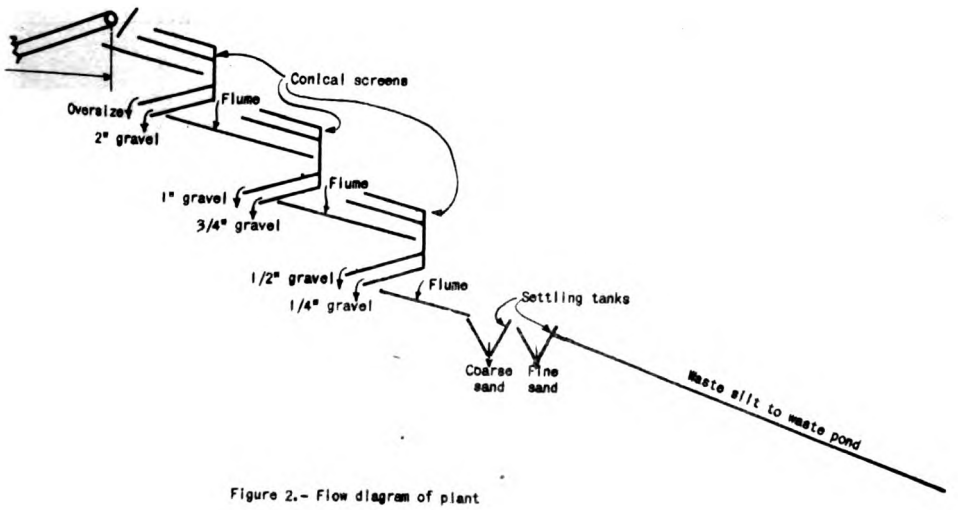


Figure 2.- Flow diagram of plant

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regate. Furthermore, these pieces of sandstone are liable to block the crusher since they will not fracture as a brittle stone would, but give without breaking. Consequently they are cast aside at the pit by the shovel.

An abandoned canal crosses the property. This canal is filled with black muck and consequently has been avoided as much as possible. The land rises to the north, and about ½ mile away where it is 45 feet higher the sand is filled with pockets of large pieces of red sandstone. Lying ½ mile further north and another 50 feet higher is a good deposit of clean sand with only 5 to 10 per cent gravel. These three types of deposit are evidently from different terraces, and presumably, of somewhat different ages. All are stratified horizontally.

The sand and gravel bank extends generally 15 to 20 feet above water level and an undetermined depth below water level—at least 30 feet, however - and is uniformly commercial to this depth.

METHODS OF PROSPECTING

Originally a roadside borrow pit disclosed the type of deposit in Farmington. A few hand-dug holes bore out the indications of this pit, and the distinctive vegetation made extensive prospecting seem unnecessary. To date, no part of the deposit has been struck which was not worth processing, except the area where the old canal is and higher up where the sand is filled with sandstone bowlders.

No prospecting costs were kept.

CHOICE OF METHOD OF MINING

Obviously, at first, under-water mining was impossible; so a drag line was used with the intention of dredging as soon as a pond of sufficient depth had been excavated. Excavation by cableway excavator disclosed the fact that the movement of subsurface water to the excavated pit was not enough to supply the plant with wash water and still maintain sufficient depth in which to float dredging equipment.

It was found that by pumping, the water could be removed from the pit, and that when pumping ceased, the water slowly returned to its original level. This lack of sufficient water prevented the use of a dredge, and the cableway excavator could, of course, cover only a limited area; so a power shovel with industrial railway was decided upon as the most economical method of mining the many years supply of material above water level.

STRIPPING

The overburden varies from 1 to 3 feet in depth. It consists of sand penetrated with a diminishing percentage of loam to a depth of about 2 or 3 feet and topped with about 6 inches of turf. It has been proved possible to wash out nearly all the loam in the plant, but to assure a clean product about 1 to 2 feet is usually stripped. The overburden is removed by either the main-pit shovel or a smaller shovel during the slack season. The material is cast into windrows about 15 feet high and of a length varying with the area stripped. The overburden, which has no commercial value, is loaded into trucks when they can be spared from the delivery department, and transported roughly 1,000 feet to low land on the adjoining property. The overburden is always moved from the company's deposit, otherwise it might have to be moved again later. It is also never dumped in the excavation since mining of that part of the deposit which is under water is contemplated in the near future.

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EXCAVATION

Excavating is handled with a 1½-yard steam shovel with caterpillar traction. The bank is excavated down to the level at which the water becomes troublesome. This generally results in a face of some 12 to 15 feet. The shovel works along the face, cutting a curved swath about 25 feet wide, and is followed by haulage tracks. When the end of the face is reached, the shovel starts back, the track being shoved close enough for loading.

A medium-grade bituminous coal has been found to be most economical for use in this shovel and in the locomotive to be described in the following section. Coal is delivered to the shovel by a horse-drawn dump cart. Water is drawn from the water hole (fig. 1) and pumped to the shovel through a 1-inch pipe line by a 2-inch centrifugal pump powered by a direct-connected, 5-hp. motor.

The excavating crew consists only of the shovel operator and fireman.

TRANSPORTATION

Two 12-cubic yard steel-lined Western bottom-dump cars transport the raw material from the bank to the hopper above the primary crushers. An 18-ton steam locomotive draws them one at a time to the switch (fig. 1), an average distance of 800 feet. This locomotive also hauls loaded cars to the railroad.

At the bottom of the incline a 1-inch cable is attached to the loaded car and a 2-drum hoist powered with a 75-hp. motor draws it up the single-track gravel incline and over a timbered trestle, a distance of approximately 200 feet. In this distance it rises 25 feet to a 15-cubic yard hopper, where the car is dumped. Dumping is controlled by a handwheel worm and gear which slackens the chains holding the bottom doors. After the doors are wound up again, the car is allowed to coast down the incline, braked by the hoist, to the switch, where it is picked up by the locomotive and the cable transferred to the other car.

The track used is 55-pound standard gage, and special effort is made to get chestnut ties, since chestnut will last through the continual wetting many times better than other local woods.

CRUSHING

Stones larger than 10 inches in diameter are caught on a bar grizzly. This grizzly, 8 feet wide by 15 feet long, consists of standard 55-pound rails, with the ball uppermost and set on the same slope as the trestle. The large stones are removed by hand. The hopper below is constructed of 3 by 6 inch oak planks bolted to braces and is lined with steel sheets. The sides slope at an angle of 55°.

Two chutes, each controlled by a 24 by 30 inch slide gate, lead the sand and gravel to two 14 by 26 inch jaw crushers, arranged tandem fashion over a conveyor belt. Each crusher is preceded by a bar grizzly constructed of narrow-gage car rails, with 2-inch spacing through which the sand and fine gravel drop directly onto the belt, thus providing a cushion for the discharge of the crusher and eliminating unnecessary wear on the belt.

The two primary crushers are run with a maximum opening of about 4 inches. They discharge directly onto No. 1 belt conveyor. Figure 2 is a flow sheet of the plant.

A mechanical vibrating screen takes the discharge from No. 1 belt conveyor and separates the plus 2½-inch stone to go through the secondary crusher while the fines drop directly to No. 2 belt conveyor. This vibrating screen is one of the company's own make, using roller bearings and having a ¼-inch throw. It is driven by an 1,800-r.p.m., 5-hp., ball-bearing motor through a single V-belt drive which cuts the speed of the screen shaft to 800 r.p.m.

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This shaft is 3-7/16 inches in diameter and is supported in bearings on each end. Equidistant on the shaft are two eccentric bearings connected directly to the screen. The eccentricity is ¼ inch in a vertical circle. The screen cloth is made of ½-inch round wire with 2-inch square openings and has an average life of 100,000 tons.

The secondary crusher is a 36 by 6 inch jaw crusher, which is closed to a 2½-inch or smaller opening. The crusher straddles No. 2 belt conveyor and discharges directly onto it.

Any necessary recrushing is handled by loading the oversize into a car under the bins, from where the locomotive takes it to the hopper above the primary crushers, to be sent through the plant again. Often the 2-inch and 1-inch sizes are recrushed in this manner to make more of the smaller sizes.

CONVEYOR SYSTEM

As shown in Figure 2, No. 1 belt conveyor runs under the two primary crushers horizontally for a distance of 18 feet, then rises on a slope of 19° for a distance of 35 feet to the vibrating screen. This slope is about as steep as is practical with this gravel. It is driven by a 15-hp., ball-bearing motor through a 6-inch, 4-ply, flat rubber belt.

No. 2 conveyor is 140 feet between centers and rises 55 feet, with 36-inch diameter head and tail pulleys. A 25-hp., ball-bearing motor drives No. 2 belt through an 8-inch, 6-ply, flat rubber belt.

Both conveyors use 36-inch, 6-ply, rubber-covered canvas belting. The rubber covering is 1/8-inch thick on the wearing side and 1/16-inch thick on the bottom. Both conveyors run at a speed of 175 feet per minute. No. 1 conveyor belt has a life of approximately 150,000 tons and No. 2 conveyor belt of approximately 500,000 tons.

WASHING AND SCREENING PLANT

At the discharge end of No. 2 belt a 4-inch stream of water is shot into the sand and gravel and aids its flow down two chutes to two parallel screen banks. More water is added in spray pipes in the screens. The total water used is about 500 gallons per minute. Each bank consists of three double conical screens, arranged to pass six sizes of material, the fines of each screen being chuted to the next screen. These sizes are as follows:

Passing	Retained on	Commercial rating of gravel
2½-inch round	1¾-inch round	2-inch
1¾ do.	1¼ do.	1-inch
1¼ do.	7/8 do.	¾-inch
7/8 do.	3/8 do.	½-inch
3/8 do.	¼ by ½ inch slots	¼-inch
¼ by ½ inch slots	-	Sand

The conical screen has several unique features. As shown in Figure 2, the gravel is introduced at one end of the screen and travels back toward the other end over the screen. The main advantage of this type of construction is that the larger sizes are disposed of first. Since the larger sizes compose a high percentage of the total and also since they require less washing than the small sizes do, it is ideal to be able to eliminate them on the first few screens. A single cylindrical screen would carry the large sizes through the whole length of the screen.

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There are disadvantages to the conical screen, chief of which is the headroom required, since the second screen must be set below the bottom of the first.

The screen head carries all the weight of the screen and the gravel in it, transmitted through angle-iron braces from the screen head. The head is a casting of the company's own design mounted on a 4-inch shaft 10 feet long. Four 6 by 6 inch angle-iron braces serve to keep the screen plate rigid. The inside screen plate is braced to these angle irons by U-shaped pieces, keeping the spacing between the two screens at 6 inches.

A slope of only 6 inches in 6 feet is used in order that the material will travel out of the screen slowly enough to insure thorough scrubbing and good separation.

The life of the screens varies considerably, but to avoid repairs in mid-season, they are generally changed at the end of each operating season, except when operation is very irregular, as at present. Probably the average life of the screens is about 150,000 tons.

WASHING AND SCREENING

Water is sprayed into each set of screens at a pressure of about 40 pounds by a 2-inch pipe with 1/16-inch perforations. The whole screen revolves in a sort of bathtub lined with sheet zinc which collects the passed fines and water to be chuted to the next screen. Zinc is used because it is less liable to corrosion, and its use obviates frequent replacements and high labor costs.

All screens in both banks are run at 20 r.p.m. by a 15-hp. motor through speed-reducing gears, sprockets, and roller chains.

The sized gravel is discharged either directly or through a short chute to the proper bin. There are no facilities for mixing the different sizes. Slide gates, 12 by 18 inches in size, operated by side levers from the ground, control the discharge of the washed and sized material to either trolley freight, trucks, or railroad cars. The sliding, on the New Haven, Northampton branch of the New York, New Haven and Hartford Railroad is about half a mile north of the plant.

SAND-SETTLING TANKS

Sand passing through the $\frac{1}{4}$ by $\frac{1}{2}$ inch mesh of the last screen is flumed over two settling tanks. While passing over the first tank the larger and heavier grains of sand settle out. This is all minus 3/8-inch and runs from 0 to 5 per cent minus 50 mesh. Going into the second tank the stream slows down past a series of three baffles which cause the finer sand particles to drop out, leaving only silt suspended in the water which is flumed to the waste field, as shown in Figure 2. The fine sand is 100 per cent minus 10 mesh and from 50 to 60 per cent minus 50 mesh.

These settling tanks are of our own make and design and are shown in Figure 3. They both discharge sand directly to bins below.

WATER SUPPLY

Water requirements for washing and screening are about 500 gallons per minute. In the spring and fall, a water hole by the plant will supply this, but during the summer water is pumped from the Farmington River into the water hole. An 8-inch centrifugal pump driven by a direct-connected, 40-hp. motor is located at the river bank and pumps through an 8-inch pipe line a distance of about 1,000 feet, discharging into the water hole. Another set-up of a similar pump and motor raises the water 57 feet to the screening tower through an 8-inch pipe line paralleling the belt conveyor. At the top of the belt this pipe is tapped and reduced as previously described.

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SAND AND GRAVEL STORAGE

A hole 12 by 12 inches has been cut in the side of the coarse-sand bin near the top and a flume has been connected at that point. Whenever this bin gets full, the wet sand washes down this flume to the coarse-sand storage pile.

There is no storage of fine sand at this plant, as only a little of it is produced here.

Gravel in excess of immediate requirements is drawn from the bins by truck and dumped in piles nearby. It is restacked with a ½-yard gasoline shovel into higher piles so as not to cover too much ground. Both the sand and gravel are loaded out of storage with the same shovel.

PERCENTAGES OF VARIOUS SIZES PRODUCED

Quantities of the different sizes produced vary considerably, chiefly due to variation in the deposit and to changes in settings of the crushers to meet market requirements. Also, occasionally, the sizes of holes in one or two of the screens have been altered somewhat in an effort to produce sizes in demand. Again the 3-inch and 2-inch sizes of stone when not in demand are often recrushed. Roughly, however, the percentages retained on screens with openings shown are as follows:

Retained on	Commercial size	Percentage of total
2½-inch	3-inch gravel	3
1¾-inch	do.	7
1¼-inch	1 do.	20
7/8-inch	¾ do.	16
3/8-inch	½ do.	8
¼ by ½ inch slots	¼ do.	3
Classifier	"B" sand (coarse)	30
Settling tank	"A" sand (fine)	10
Silt	-	3
		100

EMPLOYEE PAY SYSTEM

All employees are paid by the hour except the foreman and superintendent, who draw weekly salaries. Figure 4 is a graphic chart of the organization.

SAFETY METHODS

Safety work is carried on through the foreman, who is continually watching to avoid dangerous situations. A good safety record has been established by the company.

First-aid supplies are always on hand and use of antiseptics for any skin abrasion is compulsory.

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Table 1.- Detailed Costs

Name of pit: Atlas Sand, Gravel and Stone Co., Plant 1.
Period: Jan. 1, 1931, to Dec. 31, 1931.
Total sand and gravel mined during period: 49,840 tons.

Operating costs per dry ton of sand and gravel mined

Operation	Labor	Supervision	Power[1]	Fuel	Repairs[2] supplies	Total
Stripping (loading)	$0.0018	$0.0002	-	$0.0004	$0.0005	$0.0029
Stripping (transportation)	.0026	.0001	-	.0007	.0012	.0046
Loading (gravel)	.0174	.0010	-	.0049	.0069	.0302
Transportation (gravel)	.0321	.0020	$0.0035	.0032	.0062	.0470
Crushing, primary	.0105	.0017	.0130	-	.0066	.0318
Crushing, secondary	.0021	.0010	.0087	-	.0049	.0167
Conveying	.0021	.0005	.0056	-	.0048	.0130
Washing and screening (including water supply)	.0055	.0020	.0152	-	.0107	.0334
Storage bins and stock piling	.0114	.0010	-	.0031	.0052	.0207
Miscellaneous	.0064	.0010	.0015	-	.0050	.0139
Totals	0.0919	0.0105	0.0475	0.0123	0.0520	0.2142

1. Electric power is purchased on a sliding scale, which during this year resulted in an average price of $0.027 per kilowatt hour.
2. Includes repair labor.

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Table 2.- Summary of Costs in Units of Labor, Power, and Supplies

Name of Pit: Atlas Sand, Gravel and Stone Co., Plant 1.
Period covered: Jan. 1, 1931, to Dec. 31, 1931.
Material loaded during period: 49,840 tons.

Overburden: 3,000 cubic yards. Weight per cubic yard loose: 2,300 pounds.
Sand and gravel: 49,840 tons. Weight per cubic yard loose: 3,100 pounds.

	Stripping	Mining	Crushing	Other	Total
A. Labor: (Man-hours per ton, sand and gravel)					
Loading	0.004	0.038	0.035	0.047	0.124
Transportation	.007	.098	-	-	.105
Miscellaneous	.001	.010	-	-	.011
Supervision	.001	.004	.005	.0045	.014
Total labor	.013	.150	.040	.051	.254
Average tons per man per shift	-	-	-	-	39.3
B. Power:					
Total power:					
1. Shovels, hp.hrs. per ton	.008	.620	-	-	-
2. Locomotives, do.	-	.248	-	-	-
3. Pumping water, kw.h. per ton	-	-	-	.371	-
4. Car hoist, do.	-	-	-	.129	-
5. Crushing, do.	-	-	.804	-	-
6. Conveying, do.	-	-	-	.208	-
7. Screening and washing, do.	-	-	-	.192	-
8. Storage, hp.hrs. per ton	-	-	-	.122	-
9. Shop and lighting, kw.h. per ton	-	-	-	.055	-

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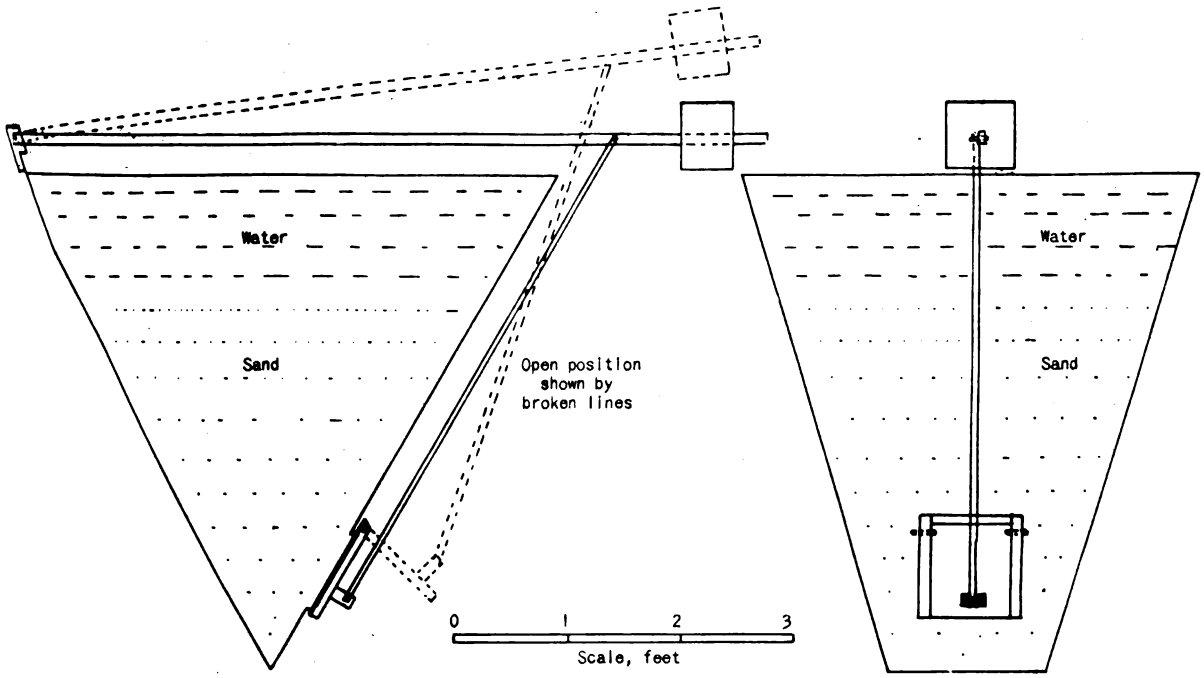

Figure 3.- Sand settling tank

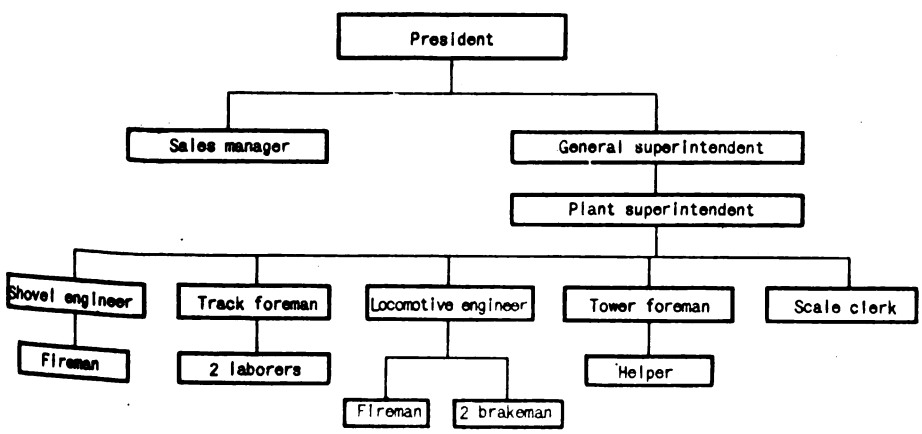

Figure 4.- Organization chart

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